Monitoring coastal storms' effects on the Trabucador barrier beach (Ebro Delta) through Sentinel-2 derived shorelines

Monitorización del efecto de los temporales en la playa de la barra del Trabucador (Delta del Ebro) mediante líneas de costa derivadas de Sentinel-2

E. Angelats[1], J. Soriano-González[2], C. Puig-Polo[3], J. Guillén[4], A. Falqués[5] and F. Ribas[5]

1 Geomatics Research Unit, CTTC/CERCA, 08860, Castelldefels (Barcelona), Spain.

2 Centro de Investigación Mariña, Universidade de Vigo, XM-1, 36310, Vigo, España.

3 DECA, Universitat Politècnica de Catalunya, 08034, Barcelona, Spain.

4 Marine Geosciences dpt, Institut de Ciències del Mar (ICM-CSIC), 08003, Barcelona, Spain.

5 Physics dpt, Universitat Politècnica de Catalunya, 08034, Barcelona, Spain.

Abstract: *The vulnerable Trabucador barrier beach has recently suffered significant storm-induced geomorphological changes. This study presents the monitoring of its shoreline during storm events for assessing their effects on beach dynamics. After fine-tuning the CoastSat tool (i.e. optimal NDWI threshold) for shoreline extraction from Sentinel-2 imagery (S2), results were validated with GNSS-RTK reference shorelines (RMSE = 6.8 m). Shorelines were extracted from Dec-2019 to Feb-2021, encompassing 11 storms (Hs > 2m; duration ≥ 24h), including Gloria (Jan-2020). Results showed that S2 imagery provides enough temporal and spatial resolution to capture the storm effects on the site. The shoreline timeseries gave relevant information about the geomorphological processes occurring during storm events (barrier breaching, erosion, washover), allowing the assessment of their cumulative effects. These results might be important for coastal management, in a site suffering from chronic flooding.*

Keywords: *Remote sensing, Sentinel-2, Shoreline extraction, Storms, Breaching*

Resumen: *La vulnerable barra del Trabucador ha sufrido recientemente importantes cambios geomorfológicos inducidos por temporales. Este estudio presenta la monitorización de su línea de costa durante tormentas para evaluar sus efectos en la dinámica de la playa. Las líneas de costa se extrajeron a partir de imágenes Sentinel-2 (S2) ajustando el código CoastSat (i.e. umbral óptimo NDWI) y se validaron con líneas de referencia GNSS-RTK (RMSE = 6.8 m). Las líneas extraídas (Dic-2019 a Feb-2021) abarcan 11 tormentas (Hs > 2m; duración ≥ 24h), incluyendo Gloria (Ene-2020). Los resultados muestran que las imágenes S2 proporcionan suficiente resolución temporal y espacial para entender los efectos de las tormentas en la zona. Las series temporales de la línea de costa proporcionan información relevante sobre los procesos geomorfológicos que ocurren durante las tormentas (rotura de la barra, erosión, washover), permitiendo la evaluación de sus efectos acumulativos. Estos resultados podrían ser importantes para la gestión de la costa, en un lugar que sufre inundación crónica.*

Palabras clave: Teledetección, Sentinel-2, Extracción línea costa, Tormentas, Rotura

1. Introduction

Most of the Ebro Delta is currently a wave-dominated coast with strong reshaping processes (Jiménez et al., 2012), highly exposed to storms and extreme events, and subjected to massive flooding, beach erosion, and overwash episodes. The Trabucador beach (Figure 1), a sandy barrier 5.5 km long and about 140 m wide (Nov-2019), is one of the most vulnerable areas of the Ebro Delta. Recently, it has suffered significant storm-induced geomorphological changes. The monitoring of shoreline, especially before and after storm events, is important to understanding the geomorphological processes associated with these events.

Recent advances in optical satellite imagery and new and open-source tools for shoreline extraction (i.e. CoastSat; Vos et al., 2019) make satellite-derived shorelines an appealing tool for monitoring these processes, in terms of cost and spatial and temporal resolutions. This study presents the monitoring of the inner and outer shorelines of the Trabucador barrier during pre and post-storm events (from Dec-2019 to Feb-2021) for assessing their effects on barrier beach dynamics using Sentinel-2 (S2) imagery.

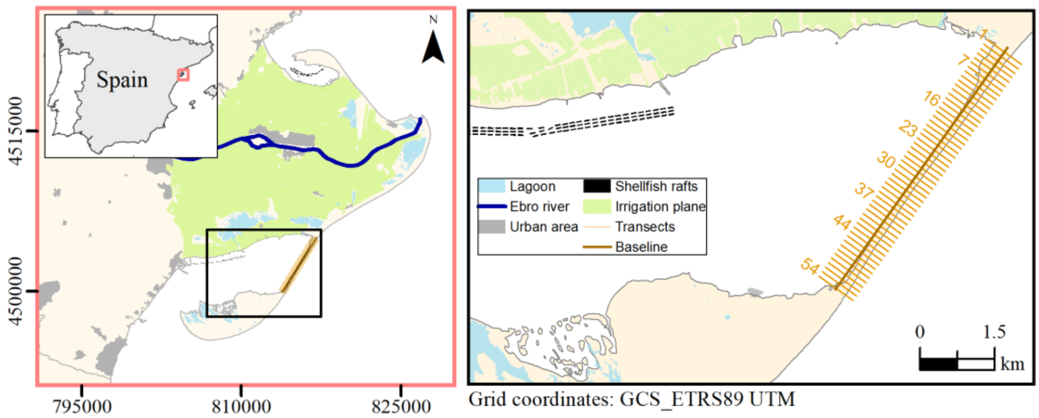

Figure 1. Location of the study area and transects analyzed.

2. Methods, Results and Discussion

Figure 2 depicts the proposed workflow to extract and analyze the S2-based shorelines of the Trabucador barrier beach. The first step included a fine-tuning of the CoastSat tool (Vos et al., 2019) for their use in Mediterranean beaches (i.e. selection of the optimal NDWI threshold). To do so, a set of 8 shorelines were extracted from two beaches (Castelldefels and Trabucador barrier) and validated with 8 GNSS-RTK reference shorelines (max time lag of 2 days, 6527 points). A RMSE of 6.8 m was obtained, thereby achieving sub-pixel shoreline detection. Subsequently, pre- and post-storm shorelines of the Trabucador barrier beach from Dec-2019 to Feb-2021 were extracted, and the inner and outer shorelines displacements and the beach width (BW) change percentage (Figure 2) were computed for each of the 54 orthogonal predefined transects (every 110 m, shown in Figure 1).

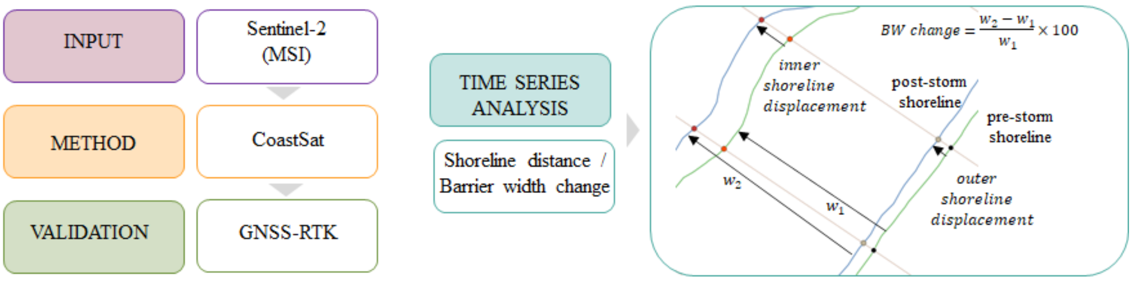

Figure 2. Proposed workflow for shoreline extraction, validation, and time series analysis

The main characteristics of the storms of the study period are detailed in Table 1. A storm class label was assigned for each storm following the approach proposed by Mendoza et al. (2011). The study period included 11 coastal storms (Hs > 2m; duration ≥ 24h), with the most extreme storm ever recorded in the area (Gloria, Jan-2020).

Sea storm	*Dates*	*Hs (m) / Tp (s)*	*Length(h)*	*Max sea level(m)*	*Wave direction range (º)*	*storm class*
December-1	3-6/12/2019	4.69 / 10	54	0.76	60-88	III
December-2	19-21/12/2019	4.28 / 8.66	50	0.57	188-202	II
Gloria	19-23/01/2020	7.49 / 11.63	96	0.66	60-110	V
March-1	2-3/03/2020	2.91 / 8.85	24	0.43	200-280	I
March-2	16-17/03/2020	3.93 / 7.7	24	0.48	70-110	I-II
End March	31/03/- 3/04/2020	3.1 / 9.14	68	0.53	64-76	II
November-1	4-7/11/2020	2.75 / 7.14	80	0.61	40-80	I-II
November-2	27-29/11/2020	3.28 / 10.55	50	0.72	67-83	II
December-1	8-9/12/2020	2.93 / 7.23	32	0.61	297-304	I
December-2	27-28/12/2020	4.34 / 10.55	25	0.54	204-229	II
Filomena	8-11/01/2021	5.74 / 11.1	60	0.66	55-77	III

Table 1. Coastal storms and characteristics during the period from Dec-2019 to Jan-2021. Wave data from the Tarragona buoy located at 688 m depth and sea level data from tidal gauge located at Tarragona harbor (Puertos del Estado).

The analysis of the shoreline timeseries (Figures 3 and 4) shown that several storms generated large or very large shoreline displacement (30 m or more), barrier retreat (Gloria, End March, Filomena), significant beach width reduction (erosion) and different levels of barrier breaching (Gloria, 1st and 2nd March, Filomena), mainly between transects 25 to 42. The results also highlight the common relation between the geomorphological effects of a storm and the elapsed time from the previous storm. For example, in the case of Gloria, the barrier had already been heavily affected by December-1 storm. The significant impact of Mar-2020 storms is also mainly explained by the previous extremely vulnerable state of the Trabucador barrier beach rather than the storm magnitudes. Figure 4 also shows some transects where the beach width increased after the storms (December-1, Gloria, End March). This could be linked to overwash episodes and the generation of washover fans. Further research will include the extension of the period of study starting from Jan-2016, to provide new insights for both research and coastal management.

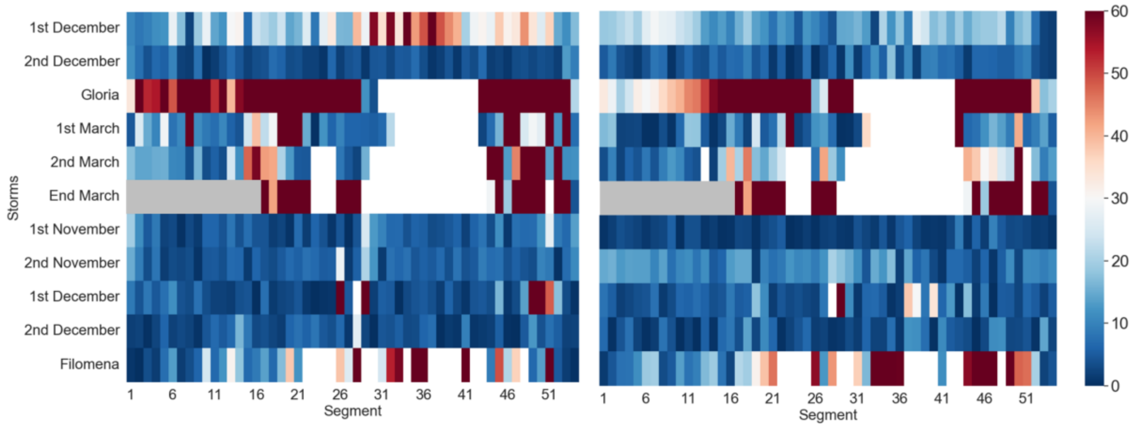

Figure 3. Time series heat-map for Trabucador barrier beach showing shoreline change in meters (left inner shore, right outer shore), where red means landward displacement (with the reddest color being displacements of 60 m or more) and blue means no displacement. White color implies transects without data because there was no shoreline (usually post-storm, i.e transects 29 to 43) or without shoreline due to clouds presence (i.e transects 1 to 17 / End March).

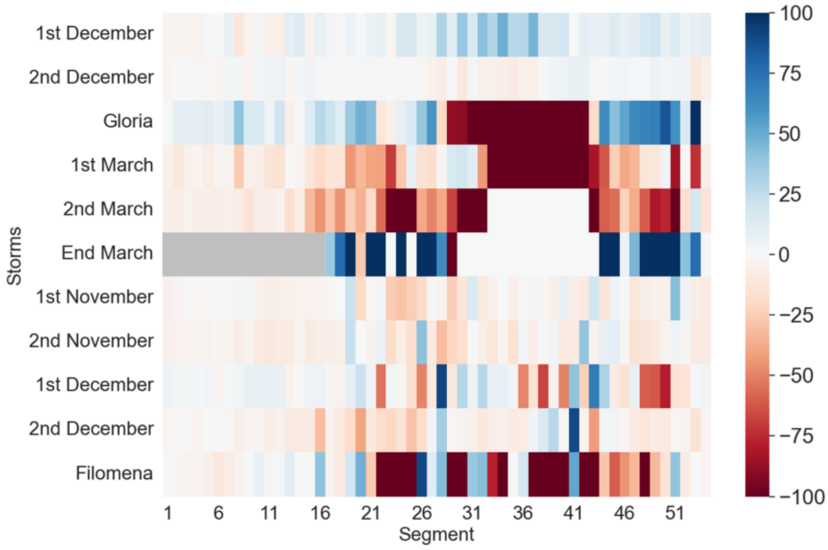

Figure 4. Time series heat-map for Trabucador barrier beach showing width changes (in %, blue being increase and red being decrease). White color implies transects without change due to no pre-storm shoreline. Grey color implies transects without data due to clouds presence.

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